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AIR-TO-GROUND TARGET ACQUISITION WITH FLARE ILLUMINATION

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13. ABSTRACT

Despite the advent of many exotic sensors for detecting targets at night, a significant portion of airborne tactical activity is carried out via direct vision, usually involving some type of artificial illumination, with air-dropped parachute flares. The use of flares constitutes one of the most difficult visual requirements for aircraft crew members attempting to detect targets at night. Efforts by the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, have involved simulating various illumination sources, and requiring subjects to detect scaled-down targets under different terrain and illumination conditions.

This paper is concerned with the results from three recent experiments. Experiment I dealt with the effect of shielding a 25,000,000-lumen flare source and determining the optimal number of flares to be used for a given target area. No statistically significant effect was found due to flare shielding. For the given target area simulated, it appeared that there was no additional benefit derived from igniting more than two flares over a simulated area of about 1.5 kilometers by 5 kilometers. Experiment II dealt with shielding of a 60,000,000-lumen source, and again, no statistically significant effect was found due to the flare shielding. Experiment III dealt with the "visual acuity" under simulated flare light. In this experiment, each of eight groups of five subjects performed at a different simulated observer altitude ranging in 152-meter increments from 152 to 1,219 meters. For the slant ranges simulated (1,029 to 1,567 meters), 610 meters was the best altitude for visual performance. Like the other findings, this could have significant impact on tactical planning for night missions. The parameters of this study have now been ~~"blown up" to real-world size~~ and the Aerospace Medical Research Laboratory, in conjunction with the Air Force Armament Laboratory, is conducting flight tests to validate the altitude data of the experimental simulations.

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AIR-TO-GROUND TARGET ACQUISITION WITH FLARE ILLUMINATION*

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SUMMARY

Despite the advent of many exotic sensors for detecting targets at night, a significant portion of airborne tactical activity is carried out via direct vision, usually involving some type of artificial illumination, with air-dropped parachute flares. The use of flares constitutes one of the most difficult visual requirements for aircraft crew members attempting to detect targets at night. Efforts by the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, have involved simulating various illumination sources, and requiring subjects to detect scaled-down targets under different terrain and illumination conditions.

This paper is concerned with the results from three recent experiments. Experiment I dealt with the effect of shielding a 25,000,000-lumen flare source and determining the optimal number of flares to be used for a given target area. No statistically significant effect was found due to flare shielding. For the given target area simulated, it appeared that there was no additional benefit derived from igniting more than two flares over a simulated area of about 1.5 kilometers by 3 kilometers. Experiment II dealt with shielding of a 60,000,000-lumen source, and again, no statistically significant effect was found due to the flare shielding. Experiment III dealt with the "visual acuity" under simulated flare light. In this experiment, each of eight groups of five subjects performed at a different simulated observer altitude ranging in 152-meter increments from 152 to 1,219 meters. For the slant ranges simulated (1,029 to 1,587 meters), 610 meters was the best altitude for visual performance. Like the other findings, this could have significant impact on tactical planning for night missions. The parameters of this study have now been "blown-up" to real-world size and the Aerospace Medical Research Laboratory, in conjunction with the Air Force Armament Laboratory, is conducting flight tests to validate the altitude data of the experimental simulations.

INTRODUCTION

One of the most difficult visual requirements for aircraft crew members involves detecting targets at night. Despite the advent of numerous exotic sensing devices, the majority of night-time aerial activity is carried on under air-dropped, parachute illumination flares. Specific problems encountered by crew members utilizing flare illumination include: restricted fields of view, visual discrimination at low levels of illumination, difficulty in tracking, terrain avoidance, visual whiteout, flare flicker and oscillation, contrast reversal, loss of depth perception, and vertigo.[1] It has also been reported that during low level flight at night, the large and frequent changes in adaption impair visual performance.[2]

There is very little literature relevant to this general problem of vision under flare light. Laboratory investigations[3] into aspects of visual air reconnaissance have been conducted and mathematical relationships for predicting performance in actual operations have been suggested. However, it has been pointed out that applications of these predictive methods to practical detection problems can lead to "great complexities".[4] An example of these "complexities" is given by Blunt and Schmelling.[5] Based upon hypothetical diffuse target-reflectance, inherent contrast, target area, range, and atmospheric effects, it was calculated that a flare of 1,445,000,000 lumens would be required to produce enough illuminance to be able to detect an armored tank located on dry sand at a range of 2,743 meters. (The most commonly used flare in the present inventory, the Naval Mark 24, produces 25,000,000 lumens). Blunt and Schmelling further point out these requirements may be increased by as much as five times when combat factors are considered (i.e., psychological stress, etc).

Therefore, it is not surprising that visual problems are encountered during night, air-to-ground tasks and that this is a difficult problem for research. Using laboratory-established relationships in their present form does not always end in reasonable recommendations for the field and attempts have been made at both laboratory simulations[6] and field studies.[7] Hamilton[6] attempted to determine night visibility distances for military targets using a scale-model simulator. Viewing paths were ground-to-ground rather than air-to-ground. It was found that visibility was poorest when targets were placed against foliated backgrounds and when the durations of illumination were short. In Wessner's[7] field study, ground targets were placed in a 2.6 square-meter area and six aerial observers flew at altitudes ranging from 762 to 1,676 meters with ranges from ground zero of 1,000 to 6,000 meters. Thirty-three flares, varying in intensity and burn-time were dropped singly. Fifteen percent of the stationary targets and five per cent of the moving targets were detected while only one percent of both types of targets were identified.

Initial simulations by the Aerospace Medical Research Laboratory used three different groups of subjects performing target acquisition (detection and recognition) tasks under simulated Mark 24 flare light, simulated Briteye flare light (a recently developed flare which produces 60,000,000 lumens), and simulated sunlight.[8,9] Generally, target acquisition took significantly longer under four simulated

* The research reported in this paper was conducted by personnel of the Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. This paper has been identified by the Aerospace Medical Research Laboratory as AMRL-TR-71-114. Further reproduction is authorized to satisfy the needs of the U. S. Government.

Mark 24 flares dropped a simulated distance of 0.4 kilometer apart and ignited at a simulated altitude of 610 meters. This compared with significantly shorter times under the simulated Briteyes deployed similarly and still shorter times under simulated sunlight (simulating those light conditions characteristic of a "partly cloudy" day). However, with the simulated Briteyes, there appeared to be a much more pronounced direct glare problem which was apparently associated with the more intense flare source. In an effort to alleviate this potential problem, efforts have been made to develop shielding techniques for flare sources.[10,11,12]

The early simulations involved attempts at scaled-down reproductions of real-world characteristics without regard to the scientific investigation of the visual system in terms of such concepts as visual acuity. Whether visual acuity is generally defined as the capacity of the eye to resolve detail, or specifically defined as the ability to discriminate black and white detail at various distances, there are many problems associated with taking purely clinical or laboratory visual acuity measurements and applying them to the field. For example, direct application of the normally accepted methods of measuring visual acuity to the field is difficult in a visual search task from an aircraft because: the eye, the platform, and the target are not static; the scene involves color; and the illumination level can be measured only generally. On the other hand, in varying the factors included (i.e., illumination, etc.), the researcher can be accused of not really measuring "visual acuity" at all, or of using a concept that was not intended to serve as a criterion bridge between laboratory and field, but rather as a precise clinical tool for determining the visual capacities of individual subjects and patients.

Yet the gap between laboratory simulation and in-flight validation must be bridged. Utilizing high fidelity terrain models can be successful. However, there is great difficulty in duplicating and controlling features similar to the terrain model in the real-world validation. The apparent alternative is to take accepted acuity measures and "modify" them for laboratory simulation and eventually "blow them up" for in-flight validation.

This paper is concerned with the results from three recent simulation experiments. Experiment I[13] was an attempt to determine the behavioral effect due to flare shielding utilizing a 1:1,000 scale terrain model and simulated shielded and unshielded flare sources. In addition, there was a concern with optimal number of flares to be used for a given target area for both shielded and unshielded Mark 24 flares. Twelve groups of subjects were used. Each group searched the terrain model under from one to six simulated flares in either the shielded or unshielded configuration. While the illuminance from a shielded flare is greater at the center of an illumination pattern, the illuminance from an unshielded flare is greater at 40 degrees from the center and beyond. Therefore, strictly from a visual performance point of view, it was necessary to determine what effect these different patterns of illumination could have on target acquisition.

Experiment II was also concerned with flare shielding. However, in this experiment simulated 60,000,000-lumen flares were used. This seemed to be a reasonable follow-on effort since an earlier study[9] had indicated that the direct-glare problem may only be associated with the more intense flare and, also, a 60,000,000-lumen flare which burns for 5 minutes is now being introduced for limited use. In this experiment, two groups of 15 subjects each searched the terrain model under two simulated flares in either the shielded or unshielded configuration.

Experiment III[14] was concerned with the optimal observer altitude for performing visually under Mark 24 flare light. (An earlier study established 610 meters as the optimal altitude for flare ignition.)[15] Another concern involves the type of measurement of visual performance. Required is a measure which is usable in the laboratory, yet expandable to real-world validation. Each of eight groups of five subjects performed at a different simulated observer altitude under simulated flare light. The simulated altitudes ranged in 152-meter increments from 152 to 1,219 meters. Landolt rings and acuity gratings were used as targets. In addition, four different brightness contrasts were used.

METHOD

Subjects

The subjects were male college students with normal color vision and 20/20 acuity or better. Color vision was tested by the Dvorine Psuedo-Isochromatic Plates. Visual acuity was tested by a Bausch and Lomb Master Ortho-Rater. Sixty, thirty, and forty subjects were used in Experiments I, II and III, respectively.

Apparatus

The main feature of the apparatus was the simulation of the flare source. The Naval Mark 24 is a commonly-used parachute flare and it produces 25,000,000 lumens for three minutes. Simulation of this flare is accomplished by use of a standard No. 47 pilot lamp.[6] Operating this lamp at appropriate voltage reasonably simulates a Mark 24 on a scale of 1:1,000. Operating a standard No. 45 pilot lamp at appropriate voltage reasonably simulates the 60,000,000-lumen flare. For experiments I and II the simulated shields consisted of modified flashlight reflectors coated with opaque white paint.

The flare simulator (Figure 1) is composed of six mechanically-driven and electronically-controlled No. 47 pilot lamps mounted on a framework suspended from the ceiling of a laboratory dark room. Each simulated flare can be manually positioned within the length and width of the framework. The descent of each flare is controlled by a 28 Volt DC motor. The voltage to each motor is a ramp function to simulate the constantly decreasing velocity in the descent of a parachute flare due to its mass loss and heat generation while burning. All six of the flares were used in Experiment I, two were used in Experiment II, and one in Experiment III.

The terrain model (Figure 2), used as the background over which the subjects searched for targets in Experiments I and II, is on a scale of 1:1,000 and presents a realistic portrayal of actual terrain. It measures 1.5 meters by 5.5 meters, which represents a terrain of about 5.5 kilometers long by 1.5 kilometers wide. The model simulates the color and reflectance properties of the real world within the visible portion of the electromagnetic spectrum and contained among others, the following features which were used as

FIGURE 1 - FLARE SIMULATOR IN OPERATION

targets for Experiment I: road, river, village, paddy area, bridge, parked truck, moving truck, moored sampan, and anti-aircraft site. Three parked trucks, three villages, and the moving sampan were used as targets in Experiment II.

In order to "fly" the subject by the terrain model in Experiments I and II, he was placed in an optometrist's chair and required to keep the back of his head against the head pads. Through the use of the chair's elevation feature, the eyes of each subject were maintained at 61 centimeters above the terrain model to correspond to a simulated altitude of about 656 meters. The chair was placed on a motorized trolley which propelled the subject along the model at a simulated speed of about 215 kilometers per hour. The non-dominant eye of each subject was covered by an eye patch since, at the actual ranges which were simulated, there would be no stereoscopic distance/depth cues.

In Experiment III, the targets used were Landolt rings and acuity gratings.[16,17,18] The Landolt ring measures minimum separable acuity or gap resolution and involves the tasks of resolution and recognition. During testing, the ring was rotated so that the gap was in one of four positions: up, down, right, or left. The acuity grating also measures minimum separable acuity and involves the task of resolution. It consists of three parallel bars with the distance between the bars equal to the thickness of a bar. The length of the bars is equal to the width of the entire configuration. During testing, the acuity grating was located in either a "horizontal" or "vertical" position.

Both the gap in the Landolt ring and the gap between the parallel bars of the acuity grating were equal to .19 centimeter. Although the use of larger targets was attempted, it was found that this size (.19 centimeter) provided the necessary discriminations among conditions for the viewing distances in this study. The targets were silkscreened with a co-polymer viscous solution onto four gray-scale shades of Kimberly-Stevens Kacel paper, Type 100 (.9 gram/square meter). This paper is a laminated material having an inner net or scrim of non-woven threads with surfacing material bonded to both sides. The backgrounds were mounted on one square foot artboard for ease of handling. Table 1 shows the brightness of the four backgrounds and the resulting brightness contrasts. These measurements were obtained with a Spectra-Brightness Spotmeter Model "SB" under indoor ambient light conditions. The brightness contrast percentages

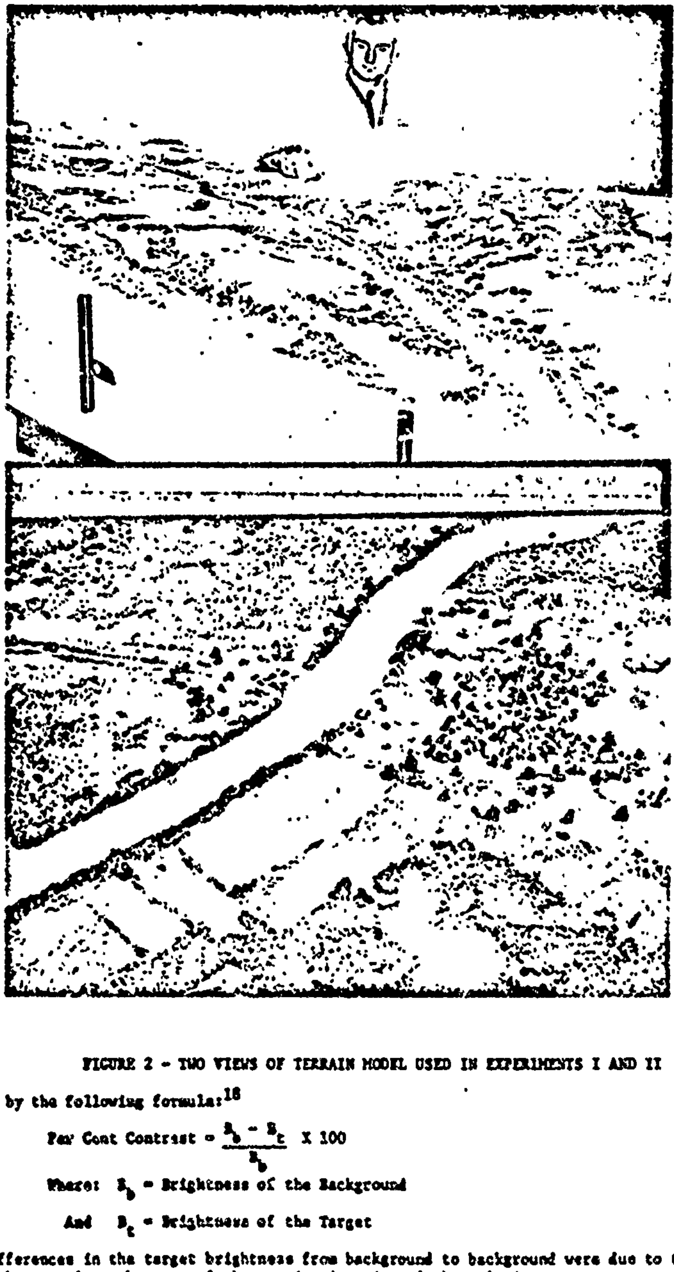

FIGURE 2 - TWO VIEWS OF TERRAIN MODEL USED IN EXPERIMENTS I AND II

were computed by the following formula:[18]

$$\text{Per Cent Contrast} = \frac{B_b - B_t}{B_b} \times 100$$

Where: B_b = Brightness of the Background

And B_t = Brightness of the Target

The slight differences in the target brightness from background to background were due to the required additions of the co-polymer because of changes in viscosity of the solution necessary to completely cover the various shades. The negative percentage of brightness contrast in Table 1 merely shows that the one target was brighter than the background.

TABLE 1

LUMINANCE IN CANDELA/SQUARE METER (cd/m²) AND CONTRAST PERCENTAGES FOR BACKGROUNDS AND TARGETS FOR EXPERIMENT III

BACKGROUND BRIGHTNESS (cd/m²)	TARGET BRIGHTNESS (cd/m²)	BRIGHTNESS CONTRAST PERCENTAGE
115	30	74
67	24	64
30	24	20
9	26	-200

Each subject was placed in the motorized optometrist's chair and was required to keep the back of his head against the head pads. Through the use of the chair's elevation feature, the eyes of each subject were maintained at 15.25, 30.50, 45.75, 61.00, 76.25, 91.50, 107.75, or 122.00 centimeters above the target surface to correspond to the simulated altitudes of about 152 through 1,219 meters. Table 2 shows the visual angles, actual and simulated altitudes and slant ranges for the eight conditions. The visual angles were computed using the following formula:[18]

$$\text{Visual Angle} = 2 \arctan \frac{L}{2D}$$

Where: L = Size of the target gap or separation.

and D = Distance from the observer's eye to the target.

Again, the non-dominant eye of each subject was covered with an eye patch since, at the actual altitudes which were simulated, there would be no stereoscopic distance/depth cues. The study was also conducted in a laboratory darkroom.

The visual angles expressed in Table 2 assume that the targets were perpendicular to the observer's eye. However, the targets were actually perpendicular to the flare source. The incident angle for the observers' eyes varied from 39°8' for simulated 1,219 meter altitude to 81°5' for the simulated 152-meter altitude.

TABLE 2

VISUAL ANGLES AND SIMULATED AND ACTUAL DISTANCES BY EXPERIMENTAL CONDITIONS FOR EXPERIMENT III

CONDITION	VISUAL ANGLE (Min & Sec)	SIMULATED ALTITUDE (Meters)	ACTUAL ALTITUDE (Centimeters)	SIMULATED SLANT RANGES (Meters)	ACTUAL SLANT RANGES (Centimeters)
1	6'25"	152	15.25	1,027	103
2	6'12"	305	30.50	1,061	106
3	5'52"	457	45.75	1,114	112
4	5'31"	610	61.00	1,185	118
5	5'10"	762	76.25	1,270	127
6	4'50"	914	91.40	1,367	137
7	4'30"	1,067	106.75	1,473	14[illegible]
8	4'8"	1,219	122.00	1,587	158

Procedure

The subjects were divided into 12 groups of 5 subjects each in Experiment I. Table 3 summarizes the conditions for each group of subjects.

TABLE 3

SUBJECT GROUP CONDITIONS FOR EXPERIMENT I

SUBJECT GROUP	NUMBER OF FLARES	IGNITION INTERVAL (SECONDS)	MODE	DISTANCE BETWEEN FLARES ACTUAL (CENTIMETER)	DISTANCE BETWEEN FLARES SIMULATED (METERS)
1	1	N/A	Shielded	N/A	N/A
2	1	N/A	Unshielded	N/A	N/A
3	2	20	Shielded	183	1,829
4	2	20	Unshielded	183	1,829
5	3	15	Shielded	137	1,372
6	3	15	Unshielded	137	1,372
7	4	12.5	Shielded	109	1,097
8	4	12.5	Unshielded	109	1,097
9	5	10	Shielded	91	914
10	5	10	Unshielded	91	914
11	6	5	Shielded	79	792
12	6	5	Unshielded	79	792

After initial screening and preliminary explanations, each subject was trained to identify the ten targets listed earlier. This was accomplished by repeatedly pointing the targets out on a smaller terrain model located in the subjects' preparatory room.

For consistency, during the experimental runs, the moving truck and sampan were always started from their respective starting points. The simulated flares were ignited at the different intervals, indicated in Table 3, to simulate a flare aircraft flying a track parallel to the simulated flight of the subject. Due to the high learning rate associated with the targets on the terrain model, each subject was used for only one experimental run.

Three types of data were recorded for each subject: total number of valid targets found; errors (i.e., identifying a truck when none was in the area); and time elapsed from ignition of the first flare to a subject's verbal response that he had detected, identified and located a target. Concerning this last variable, for any of the ten targets not detected during a run, the subject was given a response time score of 180 seconds since this was the shortest elapsed time for any of the flare conditions.

The procedure for Experiment II was similar to that for Experiment I, except two groups of 15 subjects each were established to correspond to the shielded and unshielded conditions. In addition, only two flares, placed 183 centimeters apart, were used. Concerning response times, for any of the seven targets not detected during a run, the subject was given a response time score of 300 seconds since this was the elapsed time for the 60,000,000-lumen flare.

In Experiment III, 40 subjects were used. The subjects were divided into eight groups with five subjects in each group. Each group was exposed to one observer altitude condition. In addition, all groups were exposed to the two types of targets (Landolt rings and acuity gratings) and the four brightness contrast conditions (Table 1).

After preliminary explanations and a trial run, each subject proceeded with the task of determining the position of the gap in the case of the Landolt ring or determining the orientation of the acuity grating. The order of presentation for the target and brightness contrast combinations was random. Between sessions, the subject wore opaque goggles to promote dark adaptation and also to prevent seeing target placements. The data recorded for analysis consisted of the time elapsed from ignition of the flare to a subject's correct verbal response concerning the gap of the Landolt ring or orientation of the acuity grating. If a subject was unable to determine the orientation of a target, he was given a response-time score of 180 seconds, since that was the duration of the burn time of the single simulated flare.

Design

In Experiment I, for number of targets and errors, the experimental design was a 2 x 6 factorial. The first factor refers to shielded versus unshielded modes (two levels) and the second factor refers to number of flares (six levels). For the response-time scores, the design was a 2 x 6 x 10 factorial with repeated measures on the last factor which refers to targets (ten levels).

In Experiment II, for number of targets and errors, the statistical design was a t-test with 15 subjects in each of the two groups (shielded flares and unshielded flares). For the response time scores, the design was a 2 x 7 factorial with repeated measures on the second factor which refers to targets (seven levels).

In Experiment III, the experimental design was an 8 x 2 x 4 factorial with repeated measures on the last two factors. The first factor refers to observer altitude (eight levels), the second factor refers to type of target (Landolt ring or acuity grating), and the third factor refers to brightness contrast (four levels).

RESULTS

Experiment I

The descriptive results consisting of overall means for the effects due to shielding Mark 24s are summarized in Table 4.

TABLE 4

OVERALL MEANS FOR SHIELDING VERSUS NON-SHIELDING MARK 24s

	SHIELDED FLARES	UNSHIELDED FLARES
Targets Found	6.93	7.13
Error	.77	.80
Response Time (Seconds)	97.62	97.65

In terms of overall grand means for the entire experiment, the average subject acquired about 7 (7.03) targets, took about 98 (97.64) seconds to find an average target, and committed about .8 (.83) error during an average run. The mean response-time score is very close to the overall mean (91.4 seconds) for Mark 24 flare light obtained from an earlier study[8] involving much more austere methods. None of the three variables revealed any statistically significant effects due to the flare shielding versus the non-shielding. Further, for the data consisting of number of targets acquired, there were no statistically significant effects at all. For the response time data, Table 5 reveals a statistically significant main effect due to type of target and also a significant interaction between type of target and number of flares used. These results necessitated the search for the simple main effects of number of flares for each type of target and this analysis is summarized in Table 6, which reveals that only the village, the moving sampan, and the parked truck contributed statistically significant main effects. For this reason, these three types were the only targets used in Experiment II. The zero mean square for the anti-aircraft site is attributed to the fact that it was not detected by any of the subjects in any group. The Newman Keuls tests for differences on all ordered means for the three main effects generally showed that performance with just one flare is significantly poorer than with two or more flares, but that increasing the number of flares above two does not increase visual performance for the type of

target layouts used in the experiment. The data consisting of errors also revealed a statistically significant effect due to number of flares used.

TABLE 5

SUMMARY OF ANALYSIS OF VARIANCE FOR RESPONSE TIME SCORES FOR EXPERIMENT I

SOURCE	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F
Between Subjects	101,118.900	59		
A (Shielding)	0	1		
B (No. of Flares)	7,012.000	5	1,402.400	
AB	10,643.400	5	2,128.180	
Subj w/groups	83,463.500	48	1,738.820	
Within Subjects	2,376,134.100	540		
C (Target)	1,629,618.400	9	181,068.711	150.37**
AC	10,850.400	9	1,205.600	1.00
BC	154,050.500	45	3,423.344	2.84**
ABC	61,412.700	45	1,364.727	1.13
C X Subj w/groups	520,202.100	432	1,204.172	

** $p < .01$

TABLE 6

SUMMARY OF ANALYSIS OF SIMPLE EFFECTS OF NUMBER OF FLARES FOR DIFFERENT TARGETS FOR EXPERIMENT I

SOURCE	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F
B for C_1 (River)	2,427.600	9	269.733	
B for C_2 (Road)	1,541.483	9	171.276	
B for C_3 (Village)	23,100.740	9	2,566.749	2.13*
B for C_4 (Bridge)	10,387.490	9	1,154.166	
B for C_5 (Paddy)	5,906.000	9	656.222	
B for C_6 (Moving Truck)	8,941.400	9	993.489	
B for C_7 (Moving Sampan)	69,719.490	9	7,746.610	6.43**
B for C_8 (Parked Truck)	25,393.090	9	2,821.454	2.34*
B for C_9 (Moored Sampan)	13,645.150	9	1,516.128	1.26
B for C_{10} (Anti-Aircraft)	0.0	0	0.0	
C X Subj w/groups	520,202.100	432	1,204.172	

* $p < .05$ ** $p < .01$

Experiment II

Since the target problems presented to the subjects were considerably more difficult and it was hoped, more sensitive, than those presented in Experiment I, the results from Experiment II are not comparable, for example, with the results in Table 4. For the shielded condition, the average subject acquired 4.13 targets, took 171.77 seconds to find an average target and committed 1.27 errors. For the unshielded condition, the average subject acquired 4.07 targets, took 181.13 seconds to find an average target and committed 1.93 errors. Statistical *t*-tests for the targets found and errors and the analysis of variance for the response time scores revealed no statistically significant differences due to the shielding versus unshielded condition for the 60,000,000-lumen flare.

Experiment III

Table 7 shows that considerable response time variability was found between different simulated altitudes. Table 8 shows the summary of the analysis of variance for these data.

TABLE 7

OVERALL MEAN RESPONSE TIMES BY SIMULATED ALTITUDE FOR EXPERIMENT III

SIMULATED ALTITUDE (METERS)	MEAN RESPONSE TIME (SECONDS)
152	69.49
305	39.96
457	32.74
610	5.92
762	11.41
914	8.90
1,067	39.24
1,219	35.75

TABLE 8

SUMMARY OF ANALYSIS OF VARIANCE FOR RESPONSE TIMES FOR EXPERIMENT III

SOURCE OF VARIATION	SOURCE OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F RATIO
Between Subjects	221,956.31	39		
A (Altitude)	117,305.30	7	16,757.90	5.12***
Subj w/Groups	104,651.01	32	3,270.34	
Within Subjects	523,150.82	280		
B (Type of Target)	4,125.63	1	4,125.63	12.23***
AB	6,910.64	7	987.23	2.93**
B X Subj w/Groups	10,793.63	32	337.30	
C (Brightness Contrast)	143,125.33	3	47,708.44	28.53***
AC	78,832.68	21	3,753.94	2.24***
C X Subj w/Groups	160,528.29	96	1,672.17	
BC	5,226.04	3	1,742.01	1.89
ABC	25,339.90	21	1,206.66	1.31
BC X Subj w/Groups	88,268.69	96	919.47	

** $p < .05$ *** $p < .01$

From the analysis of variance for response times, Table 8, the statistical hypothesis that there are no significant differences in response times among the eight groups is not tenable at the .01 level of confidence. The Duncan's New Multiple Range Test[19], at the .10 level of confidence indicated the results summarized in Table 9. In this table an asterisk indicates a statistically significant difference.

TABLE 9

SUMMARY OF STATISTICAL TESTS ON ALL ORDERED PAIRS OF MEANS
FOR EXPERIMENT III

SIMULATED ALTITUDE	(METERS)	610	914	762	305	1,067	457	1,219	152
	MEANS	3.920	8.90	11.41	29.96	30.24	31.74	35.75	69.49
610					*	*	*	*	*
914								*	*
762								*	*
305									*
1,067									*
457									*
1,219									*

* $p < .10$

Also, from the analysis of variance for response times, Table 8, the statistical hypothesis that there are no significant differences in response times due to type of target is not tenable at the .01 level of confidence. Rather, the data tend to indicate that the acuity gratings required significantly longer times than the Landolt rings. In addition, the statistical hypothesis that there are no significant differences in response times due to brightness contrast levels is also not tenable at the .01 level of confidence. The Duncan's New Multiple Range test at the .01 level of confidence indicated that brightness contrasts of 64 and 74 percent were associated with shorter response times than the contrasts of 20 and -200 percent. However, neither of these pairs was significantly different from one another. Finally, there was a statistically significant interaction between altitude and type of target at the .05 level of confidence and an interaction between altitude and brightness contrasts at the .01 level.

DISCUSSION

That there were no statistically significant differences due to simulated flare shielding was somewhat surprising. However, there are several other factors concerning shielding other than those involving the dependent variables used in this experiment. For example, the visual performance in this study was restricted to that associated with area search for targets of opportunity. Also, though the shield may not enhance visual performance for this type of tactical task, it will prevent illumination of the aircraft from the flare, an important consideration. An earlier study[9] indicated that the full benefit of flare shielding may not be realized until the candlepower of the flare reaches 60,000,000 lumens. Therefore, the results from Experiment III which also revealed that there was no statistically significant main effect due to flare shielding constituted a further surprise.

The results concerning number of flares are in close agreement with our earlier study[15] which disclosed no significant differences in performance when simulated .4, .8, 1.2, and 1.6 kilometer separations between flares were used. Discounting flare failure rates and other tactical maneuvers, there is no rationale for igniting more than two flares over a target area represented by the scaled-size and target features of the terrain model utilized in the experiment.

The differences attributed to type of target were anticipated. In Experiment I, most subjects detected and identified the road and river within a few seconds while the anti-aircraft site was never detected. However, for this experiment, the important targets were those which provided variability for the different experimental factors. The village, the parked truck and the moving sampan were the targets associated with

this variability. For this reason, emphasis was given to these types of targets in Experiment II. That no subject detected the anti-aircraft site was not a total surprise, since Southeast Asia returnees reported that these sites are seldom detected unless they are firing.

It is apparent from Tables 7 and 8 that for the slant range angles of this study, observer altitudes in the range of 610 to 914 meters are superior to other altitudes. Specifically, while 610 meters did not result in significantly different performances from 762 and 914 meters, the 610 meter altitude was the only one significantly better than all of the other altitude conditions. This problem now awaits field validation via an in-flight study. It is evident from the results from Experiment III that these acuity targets (1,000 times larger), placed on a controlled ground point will provide reasonable criterion measures for the inflight validation.

However, it was surprising that the acuity gratings generally were associated with poorer performance than the Landolt rings. Riggs[16] reports that in the case of acuity gratings, each single element (i.e., a single line) of the grating pattern would be clearly identifiable if it were presented alone. However, the presence of contours (i.e., other lines) makes it difficult for the observer to discriminate the separate elements of the pattern. It is reasonable to assume that even with the Landolt ring gap equal to the separation width between the grating bars, the two targets do not necessarily present the same level of difficulty in discriminating performance. In addition, Shlaer[16] found that two functions resulting from the use of these two targets to be quite dissimilar, with the Landolt ring resulting in higher visual acuity with increases in illumination. However, he concluded that both are admissable measures of visual performance.

Since visual acuity appears to be a form of brightness discrimination,[16] the significant main effect due to brightness contrast bears some importance. The results of this main effect were anticipated except for the relatively poor performance in the condition where the target was brighter than the background (BC = -200 percent). However, the general reflectances from these target/background combinations were quite low (See Table 1). In addition, traditional empirical data have shown that, for dark objects on a bright background, acuity is maximal for the highest degree of contrast between test object and background.[16] The converse may not necessarily be true.

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